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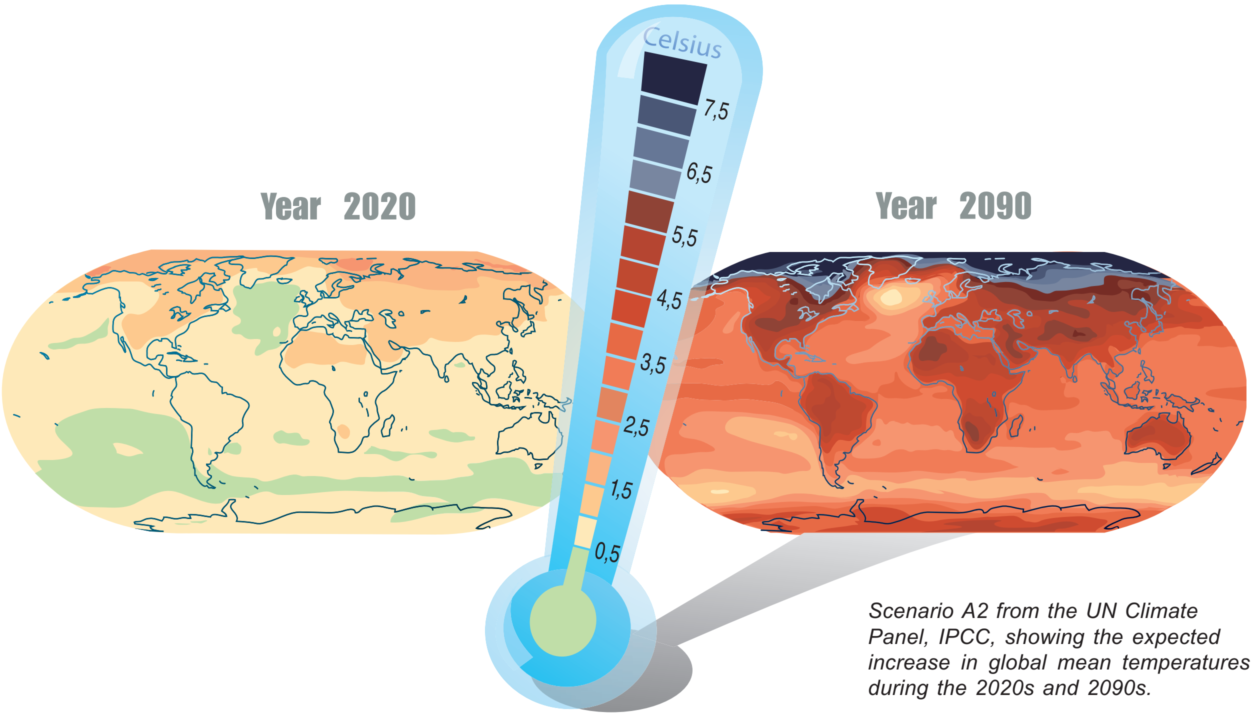
Electricity generation in the EU must be expanded, primarily with wind- and nuclear power

Nuclear Power and the Climate Change



Scenario A2 from the UN Climate Panel, IPCC, showing the expected increase in global mean temperatures during the 2020s and 2090s.

Global emissions of carbon dioxide will continue to increase at least until the middle of this century. In about 25 years, what are now the developing countries will together account for the greatest volumes of emissions. The EU position is that the industrialised countries must lead the way in introducing and demonstrating effective countermeasures. Electricity generation and transport are responsible for the greatest volumes of carbon dioxide emissions, both globally and within the EU.

This issue of Background looks at the feasibility of using bioenergy in order to solve the EU's carbon dioxide emission problems from the energy and transport sectors. The conclusion is that bioenergy can provide only a part of the solution, as land areas for cultivation of suitable crops are limited. Within as short a time as 20 years, it will be necessary for a large proportion of transport within the EU to be based on hybrid vehicle technology, with vehicles being powered by a combination of electricity and a liquid fuel – petrol, diesel oil or bio based fuels – either singly or in combination.

The energy and transport sectors will have to work together if cost efficient solutions with good security of supply are to be achieved. This could be done if EU electricity production is expanded by wind power and nuclear power, both of which are almost climate neutral.

Contents

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1. Use of fossil fuels increasing world wide

The International Energy Agency, IEA, expects global use of fossil fuels to continue to increase until at least 2030, and that the use of oil will not be restricted by availability within this period. Figure 1 illustrates the expected increases until 2030.

IEA's most recent forecast [Reference 1] is that the use of oil will increase from 3900 million tonne/year in 2002 to about 5800 million tonne/year in 2030, i.e. by almost 50 %.

This represents a slight decrease in comparison with earlier IEA forecasts, due to the effects of high prices of crude in recent years. However, expected substantial increases in demand for oil from China and India will tend to reduce the effect of higher prices.

An investigation carried out for the Centre for Strategic and International Studies (CSIS), covering the period 2000 to 2020, also expects an increase in the use of oil, although somewhat less than that forecast by the IEA, amounting to about 25-30 %.

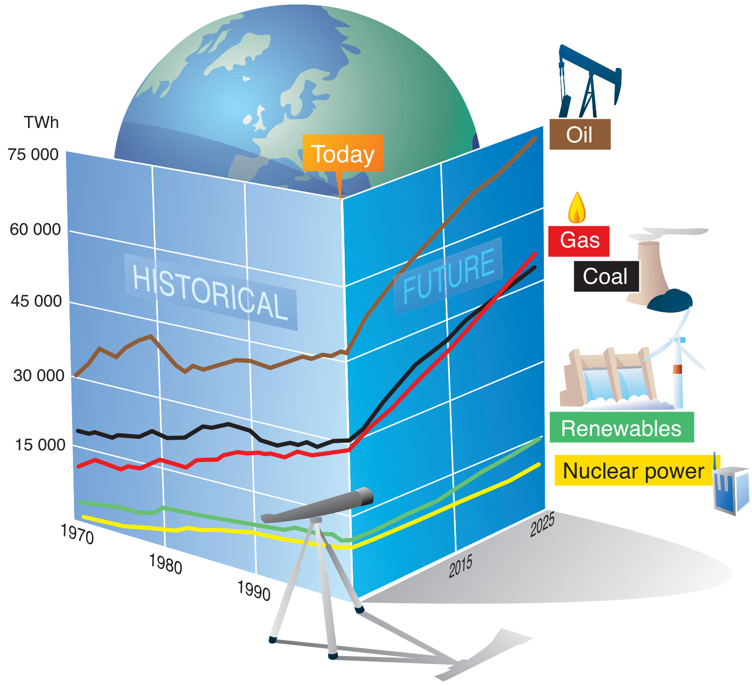


Figure 1. Use of oil, coal and gas will increase until 2025, according to the IEA World Energy Outlook 2005 forecast.

IEA also expects the global use of coal, mainly for electricity generation, to increase until 2030, although with the increase being somewhat less than that of oil in absolute terms.

Emissions of greenhouse gases – primarily carbon dioxide – arise from two dominating sources – electricity generation and traffic, as shown in Figure 2.

However, changes in global emissions depend not only on developments in these sectors, but also on world population growth, changes in the global economy and changes in land use and food supplies.

The UN Climate Panel, Intergovernmental Panel on Climate Change (IPCC) has carried out a number of scenario analyses with the aim of showing how all these possible changes could affect greenhouse gas emissions during the coming century and what effects might arise.

A palette of such scenarios and their climate consequences has been presented by the IPCC. It should be noticed in this context that climate effects consist not only of temperature changes, but also of changes in precipitation patterns, sea levels and an increase in storms and severe precipitation. Figure 3 shows four main groups of these scenarios, covering the period 1990-2100.

It can be seen that the developing countries are responsible for most of the likely increases in emission so that, by 2030, they can be expected to account for more than 50 % of emissions.

This development was already foreseen at the time of the Kyoto negotiations in 1997, where the industrialized countries that signed the agreement accepted that the developing countries would not need to reduce their emissions immediately.

Although the EU accepted this line, it was rejected by a number of others, including the USA.

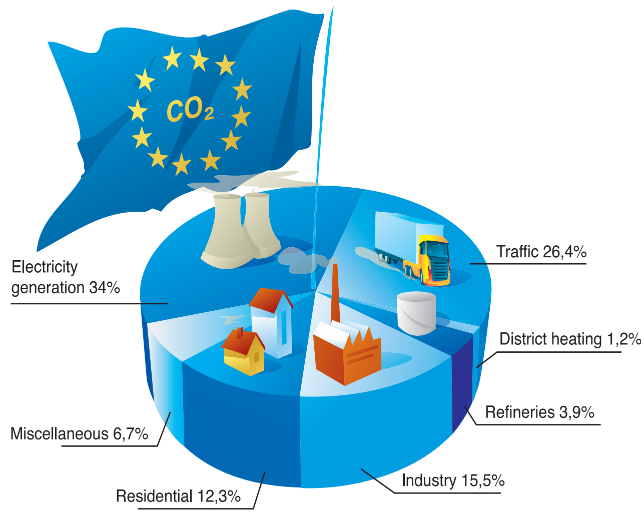


Figure 2. Carbon dioxide emissions within the EU, by sectors, 2000. Together, electricity generation and traffic account for over 60 % of carbon dioxide emissions in the EU.

2. Changes in emission levels up to 2030

2.1 Global changes

In 2005, global emissions of carbon dioxide from fossil fuels amounted to almost 29 Gtonne, with electricity generation accounting for 40 % of the emissions, and the road traffic sector for 21 %.

According to IEA, the increasing use of fossil fuels will increase fuel related carbon dioxide emissions by almost 40 % by 2030, reaching a quantity of 40 Gtonne/year.

Most of this increase is forecast to occur as a result of electricity generation, with emissions expected to increase by about 7 Gtonne/year, or by over 60 % in comparison with emission quantities in 2005. Most of this increase will be due to the use of more coal.

Carbon dioxide emissions from the transport sector are expected to increase by almost 50 %.

Figure 3 shows the expected increases in greenhouse gas emissions, as described in a number of IPCC scenarios.

IPCC: Emission scenarios in Report 4, 2007

The A1 family describes a future world with a very high economic growth, rapid introduction of new and more efficient technologies, a continuing rise in population until the middle of the century, followed by a decline in population.

The main feature of this group is an evening-out between regions, an increase in capacity and increased social and cultural exchange with a significant reduction of the regional differences in per capita income.

The A1 family is divided into three sub groups, depending on different technical development paths for the world energy system. The main characteristics of the three groups are as follows:
- A1F1 – fossil fuel intensive energy sources,
- A1T – non fossil fuel based energy sources,
- A1B – a balance between all types of energy sources.

In this context, a balance of energy sources means that, provided that all energy supply and use technologies have correspondingly improved, there is no single type of energy source upon which main reliance is placed.

The A2 family describes a heterogeneous world, based on the underlying theme of self supply and retention of local identities. In this scenario, the population development trends between regions converge only very slowly, resulting in a continuous overall population growth.

Economic development is primarily regional, with per capita income increases and technological change being more fragmented and occurring more slowly than in other scenarios.

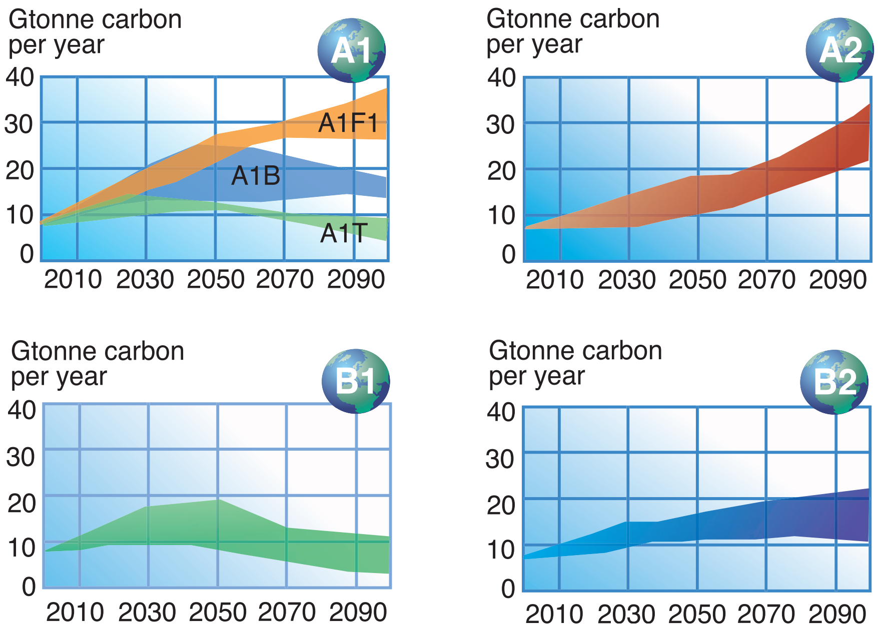
The B1 family describes a converging world with the same population pattern as A1, peaking in about 2050 and then declining, but with a more rapid change in the economic structure towards an economy based on services and information. The traditional intensity would decline, with clean and resource efficient technology being introduced.

The emphasis of this scenario is on global solutions for economic, social and environmental sustainability, of greater equality, but without further climate initiatives.

The B2 family describes a world in which the emphasis is on local solutions for economic, social and environmentally sustainable development. This is a world with a continuously growing population, but at a slower rate than in A2.

Economic development is at a medium level, with technical changes occur-ring more slowly and more scattered than in B1 or A1.

This scenario also leans towards environmental protection and social equality, but with a greater focus on local and regional levels.



Figures 3, A1, A2, B1 and B2. Four families of emission scenarios envisaged by IPCC. No allowance has been made for the effect of possible emission reductions. According to IPCC, all the scenarios are equally plausible.

In the diagrams, the y axes indicate global emissions of carbon. Quantities can be converted to carbon dioxide emissions by multiplying by 3.7.

The report also describes possible temperature changes accompanying the various scenarios at the end of the century, together with assumed resulting rises in sea level.

For the various scenarios, the global temperature rise ranges between 1.8 and 4.0 °C, with sea level rises between 0.2 and 0.6 m.

2.2 Changes within the EU

Carbon dioxide emissions from the EU25 (25 member states) in 2000 amounted to almost 3.7 Gtonne, of which the electricity sector was responsible for 34 % and the transport sector for 26 %. Figure 2 shows the proportions of emissions from these two sectors as of 2000 [Reference 3].

In this context, it is worth bearing in mind that these sectors are also responsible for significant emissions of other transboundary air pollutants.

The last decade has seen both positive and negative changes in emission levels of greenhouse gases. Positive changes include the reduction of 5 % in emissions from the energy sector between 1990 and 2000, while negative changes have seen an increase of 19 % in emissions from the transport sector over the same period.

The EU's present commitment under the Kyoto Protocol is for an 8 % reduction in carbon dioxide emissions in 2012, as compared with emission levels in 1990. The main policy measures aimed at achieving this target are as follows:

- Allocation of national emission quotas for larger stationary industrial plants, supported by emission rights trading for carbon dioxide within the framework of a trading scheme. The trading scheme does not include emissions from the transport sector.

- Directives concerning improvements in the efficiency of energy use, together with an increasing proportion of renewable energy sources for electricity and heat production.

- A voluntary directive, with the aim of persuading the transport sector to use 5.75 % of bio based motor fuels by 2010, in parallel with commitments from the automotive industry for more fuel efficient vehicles.

The aims expressed by the EU Commission for the next commitment period, i.e. after 2012, are that greenhouse gas emissions in 2020 should be preferably reduced by 30 %, and least whith 20 %, compared with the emissions in 1990.

The transport sector

Within the EU, both goods and passenger traffic are increasing rapidly. A report published by Elforsk (the Swedish Electrical Utilities R & D Company) in 2005 [Reference 2] expects a 38 % increase in goods transport between 1998 and 2010, with an increase of 21 % in passenger traffic over the same period.

Figure 4 shows the growth in transport over the last ten years.

In 2000, EU25 transport fuel requirements amounted to 3800 TWh of fuel [Reference 3]. This quantity is expected by the EU to increase to over 4600 TWh/year by 2030.

At the beginning of the 2000s, the relative proportions of road fuels within the EU were 3:1 for petrol:diesel fuel. For comparison, Sweden's motor fuels requirements amount to about 83 TWh/year.

In 2003, the EU adopted a voluntary directive (2003/30/EC) concerning the admixture of bio based fuels in motor fuel.

The objective is that bio based fuels should supply 5.75 % of the energy content of all petrol and diesel fuel for the transport sector by the end of 2010.

As a further measure, the EU Commission proposed in February 2007 that emissions from new private cars by 2012 should not exceed 120 g/km, which is a reduction of 40 g/km in comparison with the typical vehicle upon which EU policy in the transport sector has been based.

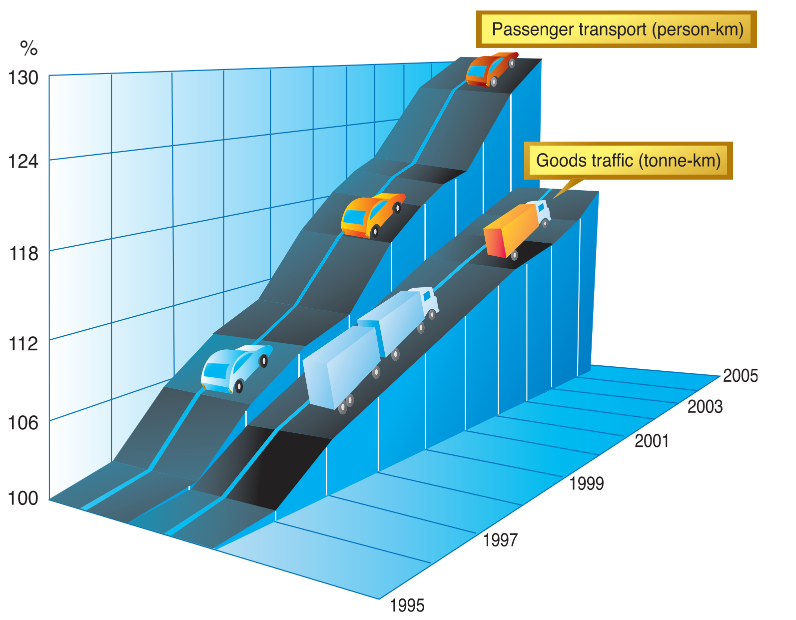


Figure 4. Transport growth within the EU25 over the period 1995-2005

The electricity sector

Under the terms of a non binding directive, the EU has set a target of reducing electricity consumption by 9 % between 2008 and 2017[1]. Despite this directive, the EU forecast as recently as 20005 that electricity use within the EU25 would increase from about 2900 TWh in 2000 to almost 4370 TWh in 2030 [Reference 3], i.e. by almost 45 %.

If the current savings target is achieved, this would mean that electricity demand in 2030 would amount to about 3840 TWh, representing a reduction of over 500 TWh in relation to earlier plans.

These forecasts have not included the possibility that the demand for electricity in the transport sector might increase as a result of the introduction of hybrid vehicles as a means of reducing carbon dioxide emissions.

This is discussed in more detail elsewhere in this report.

[1] This target was changed in March 2007 to a 20 % reduction in energy consumption by 2020.

3. The EU must secure its supplies of energy raw materials

A number of events connected with the supply of electricity, motor fuels and natural gas have shown the weaknesses of modern society.

Problems arose in the 1970s, with shortages of motor fuels, while failures of electricity and natural gas supply systems have increased in recent years, causing major problems.

One of the EU's most important objectives is therefore to secure the necessary supplies of primary energy through a combination of increased efficiency of energy use and an increased proportion of energy from renewable sources.

These measures also help to reduce greenhouse gas emissions.

Possible alternatives for present day vehicle fuels and ways of reducing greenhouse gas emissions are:

- Greater use of bio based motor fuels.
- A greater proportion of hybrid vehicles, using both electricity and fuels.
- In the longer term, the use of hydrogen as an energy source for fuel cells in vehicles.

Using hydrogen in fuel cells offers the best prospects of simultaneously achieving high energy efficiency and low carbon dioxide emissions.

However, this presupposes the successful development of fuel cells using polymer membranes.

World expertise in the sector is cautiously optimistic of the ultimate success in doing this, although warning at the same time that commercialisation is probably at least 25 years away, and that it may take up to 40 years before the necessary break-through occurs.

This is a message that has been heard for over 20 years, and so we are effectively referred to the second alternative in order to reduce our dependence on oil and emissions of greenhouse gases.

Various forms of bioenergy are now being increasingly used both for electricity and heat production: international trading has become established in order to meet the demands of growing markets.

The question is whether possible production areas of land for biomass can suffice to provide both transport and energy sectors with the necessary quantities of biofuels that will be needed in about 25 years.

4. Can the transport sector meet stricter climate commitments?

As previously mentioned, the objective for the transport sector is that, by 2010, 5.75 % of its energy input should be supplied by bio based motor fuels.

By 2030, this target should have been achieved, by which time it could well be that bio based motor fuels are providing 10 % or more of the required energy.

However, even with as optimistic a proportion as 15 % contribution, carbon dioxide emissions from the transport sector would increase by almost 10 % by 2030, based on the figures given in the EU's motor fuels forecast [Reference 3]. It is not improbable that, by 2030, the EU's climate objective would include a commitment to reduce emissions by 30 % in comparison with 1990.

If, by this time, the only way of meeting this would be to ensure a contribution of 15 % of bio based fuels for transport, the consequence would be that other sectors would have to reduce their emissions by getting on for 50 %.

Other measures within the transport sector therefore seem reasonable and likely. One possible measure which, at first sight, could seem attractive would be to include the transport sector in the emissions trading scheme.

However, this could be dangerous in economic terms, as the transport sector has hitherto shown itself to be relatively insensitive to fuel price rises. It is therefore likely that this would continue to be the case if the sector was required to purchase carbon dioxide emission rights.

The result would be major cost increases for stationary plants emitting carbon dioxide, and reduce of the EU's competitiveness with the rest of the world.

Further development of hybrid vehicles seems to pave one way, even in short terms, to reduce carbon dioxide emissions.

Figure 5 shows a schematic diagram of a hybrid vehicle, while Figure 6 shows corresponding energy and environmental data. In this context, it is worth noting that the Eucar organisation believes that, in terms of total energy requirements for motor fuels, a change to bio based fuels would achieve only a marginal difference.

It is estimated that the drive power requirement for conventional diesel fuel and for biodiesel would amount to about 0.47-0.50 kWh/km.

For a conventional Otto engine, almost 0.53 kWh/km would be required, whether in the form of petrol or ethanol.

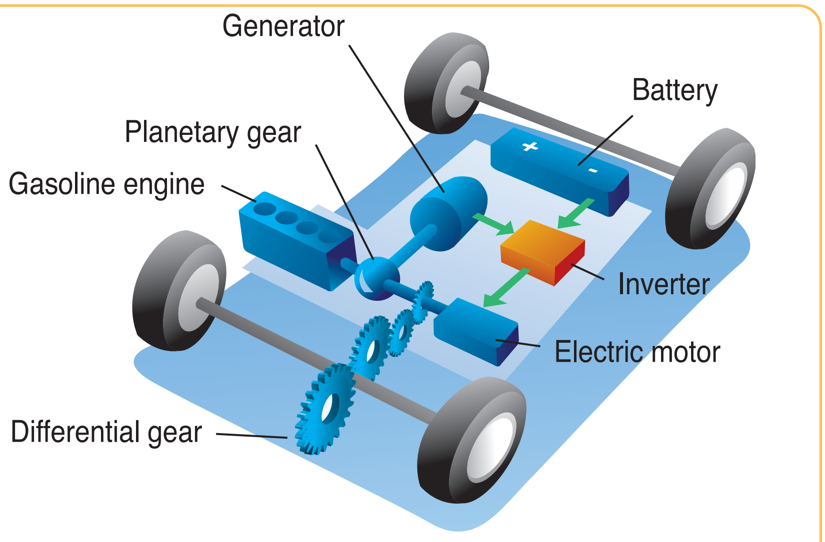


Figure 5. Schematic diagram of a hybrid vehicle, as published by Toyota.
www.hybridsynergydrive.com

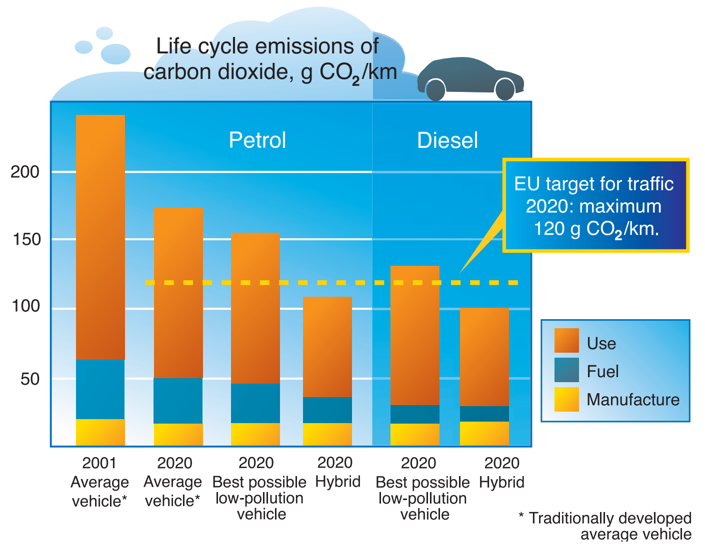


Figure 6. Carbon dioxide emissions of petrol and diesel vehicles in a life cycle perspective (Reference 2).

Starting from the specified data, the EU target of 120 g CO_2/km seems very reasonable, and should be achieved as the result of existing plans.

5. Biofuels can provide only a partial solution

Bio based motor fuels are primarily:

1. Biogas – a mixture of methane and carbon dioxide – which, after removal of the carbon dioxide, can be used in the same way as natural gas. Biogas is produced by anaerobic digestion of various wastes,

2. Ethanol, which is today mainly used as an additive in petrol, but which can also be used as a fuel on its own. It can be produced from waste products rich in sugars such as sugar cane or sugar beet, from grain crops or from forest waste.

The first plant making large scale use of forest felling residues was commissioned in 2006 in Canada [Reference 4].

Sweden is conducting pilot scale trials in a new plant, producing ethanol from forest felling residues such as branches and tops.

3. Ethers and esters, which can be used in both Otto engines and diesel engines, and which can be produced from various grain crops.

The automotive sector is highly international, with vehicles being mass produced for world markets and being widely used in international transport.

This means that unilateral national solutions for bio based motor fuels are unrealistic: instead, engine concepts and types of fuels need to be internationally standardised.

5.1 Insufficient land areas within the EU

At the beginning of the 2000s, world production of bio based motor fuels represented only a few percent of total world use of such fuels.

This is due to the fact that bio based fuels have been considerably more expensive than petrol or diesel fuel, and that vehicles have been only marginally suited to the use of such fuels. Figure 7 shows production data for the EU, for the USA and Canada, and for Brazil.

In 2003/2004, bio based motor fuels produced in Sweden supplied about 0.5 TWh, or 0.6 % of the demand for fuels. Four new production plants are planned for opening in 2008, raising Swedish production to 314 000 tonnes/ year, or 2.3 TWh.

The report entitled *Renewable motor fuels – national target for 2005 and increasing the availability of such fuels* (SOU 2004:4), estimated that, over about a 20 year period, production of ethanol could amount to about 10 TWh/year. The report assumed that raw material for the major increase would come from felling residues from forestry.

Present day production of bio based motor fuels in the EU25 as a whole is somewhat less than 27 TWh/year, or 0.7 % of the demand for fuels.

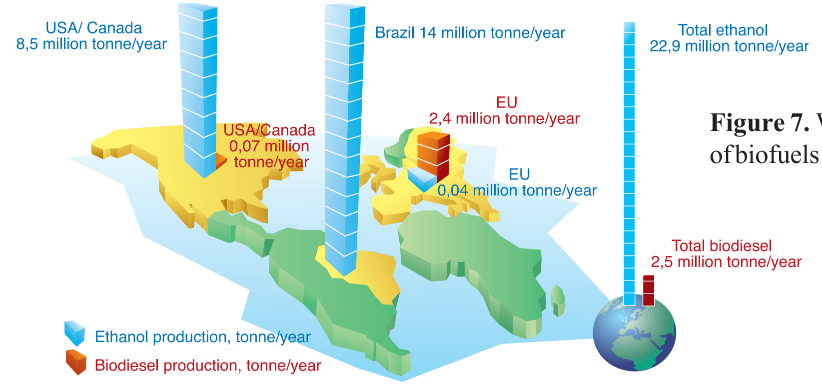


Figure 7. World production of biofuels in 2003/2004.

Agriculture becomes a primary producer of bioenergy

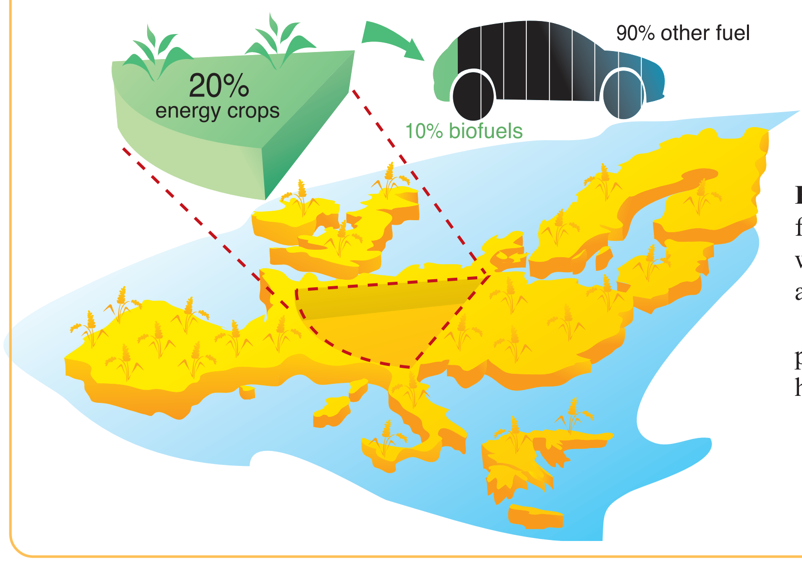


Figure 8. Replacing 10 % of the demand for petrol and diesel fuels within EU25 would require almost 20 % of the total agricultural area to be used.

This also assumes that specific yield per unit of land area would be about 50 % higher than today.

Bio based motor fuels

Within the EU, the agricultural yield in the form of bio based motor fuels is considerably greater for ethanol than for biodiesel. Sugar beet can produce up to 5.5 m≈ ethanol/hectare, while wheat can produce 2.5 m≈.

Unfortunately, land areas suitable for sugar beet are only about 10 % of areas suitable for wheat, which means that the average present day yield does not exceed about 2.8 m≈ ethanol/hectare, or 21 MWh/hectare.

As far as Sweden is concerned, a dissertation at the Swedish University of Agricultural Sciences indicates that the net yield may be as low as 4.8-4.9 MWh/hectare [Reference 5].

According to the IEA, improvement of the raw material crops for ethanol or biodiesel should be able to provide considerably better harvests within the EU. Even by 2010, it should be possible to achieve an ethanol yield of 4.8 m≈/hectare, rising to 5.9 m≈/hectare by 2020.

The corresponding figures for biodiesel are 1.4 m≈/hectare and 1.6 m≈/hectare respectively, which can be compared with the present day yield of 1.1 m≈/hectare.

At present, replacing 10 % of the EU25 requirement for motor fuels would require 23 million hectares of agricultural land, or almost 25 % of the total agricultural area within EU25.

Over a ten year period, improvements in the crops could reduce the land area to about 18 million hectares, with a further reduction to about 15 million hectares over 20 years.

This would bring the necessary land area down to about 20 % of total agricultural area.

Bio based motor fuels can therefore provide only a partial solution to the transport sector in terms of reducing carbon dioxide emissions and dependence on oil.

5.2 The energy and transport sectors will probably have to work together

Each year, the Swedish commercial energy sector uses about 47 TWh of fuels, of which wood fuels make up almost 40 %. The quantity of fossil fuels, amounting to about 25 %, will probably fall to below 20 % as a result of the increasing replacement of coal by various forms of biofuels.

It must also be noted that bioenergy is used in the pulp and paper industry, with black liquors and bark being the main fuels.

The Swedish energy sector is therefore already a large user of bioenergy, which raises the question of how competition for bioenergy will develop.

Using data from the funding application for the new Swedish pilot plant for the production of ethanol from felling residues, it can be seen that only about 35 % of the dry substance of the wood is converted to ethanol.

In order to keep production costs down, it will be essential to build ethanol plants in the form of energy combinates, supplying electricity, district heating and secondary biomass.

The total energy quantity that such secondary energy flows could deliver can be calculated as about 17 TWh/year when producing 10 TWh of ethanol from forest biomass. This quantity of energy is about the same as present day use of biofuels in district heating and CHP plants.

In addition, ethanol will also probably be produced from agricultural crops. In this case, the yield does not exceed 50 %, and so it will also be necessary to build such plants in the form of energy combinates, which means that there will be an additional source of supply of biofuels to the market.

It can be seen from this that the coming demand for bio based motor fuels from the transport sector need not necessarily become an impossible competitor to the Swedish energy sector.

If anything, the common increased demand should result in economies of scale in the primary production stage and in the construction of combinate plants.

In the same way, symbiotic relationships will probably develop between the transport sector and the energy sector in other parts of the EU.

6. EU electricity generation needs to be expanded

At the meeting of the EU Council of Ministers in March 2007, it was stated that it was expected that the demand for electricity in the EU25 would increase by almost 32 % over the period 2000 to 2030. This increase excludes that expected in the transport sector as a result of stricter environmental requirements.

One scenario for the transport sector is that growth would occur as described in Section 2, but with carbon dioxide emissions being 25 % less in 2020 than they were in 2000, and with an increase in the use of bio based motor fuels to 10 % of the consumption of petrol and diesel fuel.

Under this scenario, it would be necessary for no less than 70 % of vehicles to be of hybrid type in order to meet the climate requirements.

Achieving such a high proportion of hybrid vehicles is hardly reasonable, bearing in the mind the fact that such vehicles are still under development.

However, the proportion of hybrid vehicles might have reached 25 % by 2020, followed by a rapid increase over the next decade powered by environmental pressures.

This calculation can be compared with the conclusions reached by a 1999 investigation by Elforsk [Reference 6], that the proportion of hybrid vehicles among new vehicle sales would have reached 80 % by 2010.

The report assumed that the amount of electricity for future hybrid vehicles of the plug in type would amount to 0.15 kWh/km in 2010.

This figure is in good agreement with that reached by the California Cars Initiative which, in June 2005, arrived at a figure of 0.16 kWh/km for medium sized cars, and 0.19 kWh/km for larger vehicles. Both these figures are based on investi-gations carried out by the Electric Power Research Institute, EPRI.

If hybrid vehicles of the plug in type made up 25 % of vehicles in use in 2020 within the EU25, they would require an electrical energy demand of the order of 600 TWh/year.

This must be added to the EU's value which, excluding electrical energy for the transport sector, is forecast as over 3500 TWh/year in 2020.

It has been assumed in the above calculations that the electricity that would be used to power hybrid vehicles would be produced without associated carbon dioxide emissions.

This is a natural assumption, as all the climate benefits of hybrid vehicles would be lost if the specific carbon dioxide emission from their requisite electricity generation exceeds 330 g/kWh of electricity (see Figure 6).

This requirement therefore disqualifies electricity generation from fossil fuels, unless the CO_2 is separated from the flue gases.

6.1 Environmental benefits and economics show the benefits of nuclear power

From the earlier sections of this report, we have learnt that:

1. The annual electricity demand within the EU25 is expected to increase by 1000-1200 TWh/year over the period until 2020, to be followed by a further rise of about 1000 TWh/year over the next decade. These higher growth values are based on the assumption of an aggressive EU climate policy, and that the policy will also include the transport sector.

2. This increasing electricity generation must be accompanied by very low CO_2 emissions.

3. It is likely that the energy and transport sectors will have to work together within the next quarter century, which will mean that matters relating to secured supplies of primary energy will be of prime importance.

New hydro power can provide only a marginal input within the EU, while power generation based on natural gas would make the EU extremely vulnerable to any import disturbances.

Wind power, new nuclear power and coal based electricity generation, in combination with removal and sequestration of CO_2 in underground aquifers, can therefore be seen as ways forward for the EU to increase electricity production over the next 25 years.

Separation of carbon dioxide has a substantial long term potential in Europe. However, a drawback of this is that it reduces the total overall efficiency by almost 20 %, thus using up fuels more rapidly.

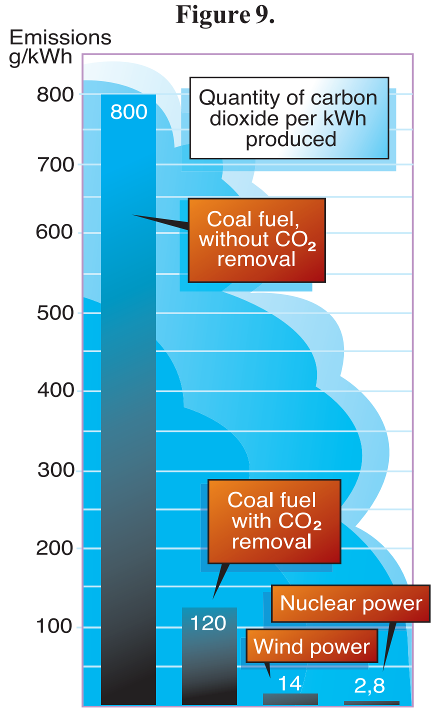
As far as assessing the environmental consequences of different forms of generation of electricity is concerned, considerable help can be obtained from environmental impact assessments.

In Sweden, these assessments are reviewed and registered by the Swedish Environmental Management Council, from whose website information has been obtained on electricity from wind power and nuclear power plants, as shown in Figure 9.

In several reports [Reference 7], Elforsk has described various technologies for the separation and storage of carbon dioxide emissions from electricity generation. For coal fired plants, net emissions are about 100-130 g/kWh if CO_2 is sepa-rated, as against about 800 g/kWh if it is not separated (see Figure 9).

If the target is to achieve low carbon dioxide, particulates and acidifying substance emissions, and to minimise effects on the stratospheric ozone layer, it will be necessary to turn to nuclear power and wind power as the most suitable, with their almost climate neutral electricity generation.

Figure 9.



Economy

In its report *'Electricity from new generation plants'* [Reference 8], Elforsk has calculated the net production cost of wind power (i.e. without allowing for taxation, subsidies or standby power generation capacity)[2] as between SEK 0.38 and 0.42/kWh, with an assumed real rate of interest of 6 %.

An IEA/NEA report for European power generation [Reference 9] has come to the same figure for the cost of wind power generation.

With the same conditions as for wind power plants, the cost of electricity generation from coal, with CO_2 separation, has been calculated as amounting to between SEK 0.45 and 0.53/kWh.

In addition, to this must be added the trading costs for unavoidable CO_2 emissions, amounting to about SEK 0.02/kWh.

The cost of new nuclear power generation has here been calculated using official figures for the fifth Finnish nuclear power station, Olkiluoto 3. The power utility, Teollisuuden Voima Oy, has stated to the EU Commission that the capital cost has been calculated as amounting to EUR 3400 million, for an electrical output of 1600 MW.

The Institution of Energy Technology[3] at Lappeenranta University of Technology has previously published data for the variable/fixed costs of the plant. From this material, the generation cost has been calculated as SEK 0.26/kWh[4].

[2] The need for standby production capacity for wind power is due to the fact that wind power units are stopped in wind speeds exceeding 25 m/s. This means that, even with a wind power production of about 10 TWh/year, the Swedish power system needs a capacity reserve of the order of 600-800 MW.

[3] Risto Tarjanne and Sauli Rissanen, February 200.

[4] Assuming a real rate of interest of 6 %, an economic life of 40 years and an operational availability of 8000 h/year.

6.2 What is a new generation of nuclear power

The Analysis Group's Background publication '*Nuclear Power in the World*' [Reference 10], describes the situation for nuclear power in various countries, together with possible developments available in the fairly near future. Some of the main points are:

1. Supplies of uranium will last for centuries or more, even though there may be a very substantial development of nuclear power generation.

2. There is now an aggregated worldwide operational experience of light water reactors amounting to more than 10 000 reactor years. This experience has been applied in the development of several important design improvements of new nuclear power plants now offered on the market, for such points as:

- Greater safety, with very low risk of core meltdown
- Improved operational safety, with resulting high availability
- Improved operating costs
- Improved maintenance and checking facilities
- Shorter construction times

3. Everything therefore indicates that all nuclear power stations that are ordered on commercial terms over the next ten years will be based on light water reactors that have been developed and improved from the existing generation of reactors.

4. New reactor types that may be ordered over the next 10-15 years include a gas cooled reactor with fuel in the form of 'pebbles' about the size of tennis balls. Technical development work has been concentrated in South Africa, based on German designs developed during the 1980s. Similar development work is in progress in China.

The South African reactor is known as a Pebble Bed Modular Reactor (PBMR). It is cooled with helium having an exit temperature of 900 °C, powering a gas turbine in a direct cycle and having a total efficiency of 42 %, which can be compared with the current light water reactor's 33 % efficiency.

7. Summary

One of the assumptions behind this analysis is that the EU will continue to be a driving force for reducing emissions of greenhouse gases, with the aim of reducing 2020 emissions to at least 20 % less than emissions in 1990, and with a further reduction to 30 % less by 2030.

It is not very likely that the EU will unilaterally apply emission reduction measures to stationary industrial plant. On the contrary, many factors indicate that it is the transport sector that must reduce its emissions.

In order to achieve the established targets, it will not be sufficient simply to improve the design of present day vehicle engines.

Nor, looking ahead 25 years, is it sufficient to concentrate solely on bio based motor fuels, although they may very well provide parts of the solution.

If the transport sector is to be able to reduce its emissions at the same rate as for stationary plants, it will be essential that hybrid vehicles of the plug in type achieve a substantial proportion of the market.

The electricity used in hybrid vehicles converts the stored electrical energy into kinetic energy in a very efficient manner.

Another advantage is that such vehicles can use regenerative braking, i.e. which returns some of the kinetic energy to the vehicle's batteries.

This significantly improves the total efficiency to a level considerably higher than could be achieved by further development of present day internal combustion engine designs.

For the EU25 as a whole, the demand for electricity for hybrid vehicles could be of the order of 1000 TWh/year, or 25 % of the electricity that would otherwise be needed to meet the market demand.

Hybrid vehicles of the plug in type are environmentally efficient if the electricity that they use is generated with very low associated carbon dioxide emissions.

Attempting to integrate the electricity generation and transport systems within the EU would require very strict demands in terms of reliable supplies of primary energy. This means that only wind power, nuclear power (further developed from present day designs) and coal fired plants with CO_2 separation can be considered in the long term.

However, in practice, coal based generation systems can never be entirely CO_2 free.

In this respect, such systems are less desirable than the other two alternatives, and can also be expected to have costs of the order of 20-25 % higher.

Environmentally, wind power is an excellent generation source, but cannot be expanded indefinitely to more or less any size.

This is because generation ceases, not only in the absence of wind, but also during times of high winds, which requires some suitable form of standby generation capacity.

Even with such a relatively modest contribution as about 10 TWh/year to the Swedish electricity system, this would mean that there must be about 600-800 MW of standby capacity available.

In a life cycle perspective, nuclear power would probably have a somewhat lower total CO_2 emission than that of wind power.

In addition, nuclear power generation costs are expected to be lower than those of wind power, with a superior generation potential.

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Note: References 2, 6, 7, 8 and 10, of which the titles have been translated for this list of references, are in Swedish.

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